Remarks

This preliminary amendment is presented to broaden the scope of certain claims and to correct math errors that had been found in the specification. The essence of the teaching of the specification of utilizing a high powered hot gas stream to treat a wafer while establishing a temperature differential throughout the thickness of the wafer to quench has not been changed.

Respectfully submitted,

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Version with Markings to Show Changes Made to Specification

For this approximate physical model, we consider the substrate as three equal layers each of thickness $\Delta h/3$. We estimate the temperature rise of the top, directly heated layer and then compare this to an estimate of the heat transferred through the middle layer to the back layer to give an upper value for the exposure time t_E to the heat flux that gives a large temperature differential through the thickness. If the top layer were thermally isolated, equation (6) gives the temperature rise ΔT for the exposure time t_E with an input heating power W to the top layer of thickness $\Delta h/3$ as:

$$(14) \quad \Delta T = 3W\, t_E / \rho\, c_p \Delta h$$

We now estimate the heat transferred through the middle layer, thickness $\Delta h/3$, to the back layer during the exposure time t_E. We use equation (154) to estimate the temperature difference across the middle layer as $\Delta T/$~~2~~4 (e.g., $\sim\Delta T/2$ for the top layer, $\sim\frac{1}{2}(\Delta T/2)$ for both middle and bottom layers. ~~For there to be a large temperature difference through the wafer thickness when exposure to the heat flux has ended, the heat transferred to the back layer must be significantly smaller than the heat input into the front surface. Since the back layer is one third the total wafer thickness we use:~~

~~Heat transfer rate to back layer = (½)(W/3) = W/6~~

~~as an upper value for estimating onset of the regime for a large temperature differential.~~ Equation (13) then gives for the heat transfer through the middle layer to the back layer as:

$$\text{(area) } W/\cancel{6} = k \text{ (area) } (\Delta T/\cancel{4}2) / (\Delta h/3)$$

(15) $W = \cancel{9}\underline{(3/4)}k\Delta T/\Delta h$

Substituting for ΔT from equation (14) and ~~the~~ solving for t_E gives the estimate for the upper bound to the exposure time for the regime with a large temperature differential as:

(16) $t_E < \underline{(4/9)}\rho\, c_p \Delta h^2 / \cancel{27}k$

We note that this expression does not explicitly contain the input heating power; however since the heat capacity c_p and the thermal conductivity k are somewhat temperature dependent for all materials there is an implicit dependence on the heat input by way of the temperature dependence of these variables.

For the case of a silicon wafer for heating to a peak temperature above 1200 degrees C, representative values for the variables in (16) are: ρ = ~~28.1~~<u>2.33x10^3</u> Kg/m^3; c_p = 700 J/(kg degrees C); Δh = .75x10^{-3}m and k = 40 W/(m degrees C) which give:

<u>Version with Markings to Show Changes Made to the Claims</u>

1. <u>(Amended)</u> A method for rapid thermal processing (RTP) of a substrate used to make semiconductor devices comprising the steps of:

forming a hot gas stream whose <u>temperature is substantially above a peak substrate surface temperature obtained during thermal processing of the substrate by the hot gas stream</u> [~~power density is above about 5x10^7 W/m^2~~]; ~~;~~ and

moving a substrate through the hot gas stream at a speed selected to treat <u>an area of</u> the surface of the substrate at a high <u>peak</u> temperature while <u>establishing</u> [~~pre-~~

~~serving~~]-a temperature differential throughout the thickness of the substrate to enable the substrate to produce enhanced cooling of a treated area of the substrate by thermal conduction into the bulk of the substrate after the treated area has passed out of the hot gas stream.

2. (Amended) The method as claimed in claim 1 wherein the power density of the hot gas stream is above about 58x10^7 W/m^2.

3. (Amended) The method as claimed in claim 1 wherein the exposure time t_E of said treated area of the substrate to the hot gas stream is less than a value given by the expression: $t_E <$ ~0.4$\rho\, c_p \Delta h^2 / \cancel{27}k$.

5. (Amended) The method as claimed in claim 1 for a silicon substrate wherein the velocity of the substrate is selected sufficiently high to yield an exposure time of any treated area on the substrate to the hot gas stream of less than about 8ms.

7. (Amended) The method as claimed in claim wherein said substrate is held in a substrate holder of the non-contact vortex type and wherein said substrate holder has an extension beyond the substrate edge, said extension extendings out from the substrate for a distance greater than the characteristic width of the hot gas stream treatment area.

10. (Amended) The method as claimed in claim 1 and further including the step of diffusing doping atoms from the hot gas stream wherein a material containing the doping atoms was ~~were~~ injected into the hot gas stream.

18. (Amended) The method of claim 1 [13] wherein said movement of the substrate is controlled to provide multiple overlapping passes with sufficient intervals between adjacent passes to enable a portion of the substrate exposed to the hot gas stream during

a previous pass to cool to a desired level for a generally uniform thermal treatment of the entire substrate while establishing said temperture differential.

19. (Amended) The method as claimed in claim 1 [13] wherein said substrate has a motion configuration wherein the substrate moves through the hot gas stream with a step and scan motion such that the substrate moves with sequential, off-set passes through the hot gas stream with a controlled velocity along linear paths.

20. (Amended) The method as claimed in claim 1 [13] wherein said substrate has a motion configuration wherein the substrate moves through the hot gas stream with a step and scan motion such that the substrate moves with sequential, off-set passes through the hot gas stream with a controlled velocity along paths that are arcuate.

21. (Amended) The method as claimed in claim 13 wherein the motion of the substrate is along overlapping scans while providing a [to provide a greater] cool-down time between scans with [sets of] scans which are off-set from each other where:

scans in each set are ~~is~~ greater in dimension than the characteristic width of the hot gas treatment area;

~~the~~ subsequent sets of scans are offset by sufficiently small steps to give uniform treatment and

sets of scans are run to fully treat the entire substrate.